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SUSTAINED/CONTINUOUS OPERATIONS SUBGROUP OF THE DEPARTMENT OF DEFENSE HUMAN FACTORS ENGINEERING TECHNICAL GROUP: PROGRAM SUMMARY AND ABSTRACTS FROM THE 9th SEMIANNUAL MEETING

Compiled by D.F. Neri and R.E. Gadolin

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The 9th semiannual meeting of the Sustained/Continuous Operations Subgroup of the Department of Defense Human Factors Engineering Technical Group (DOD HFE SUSOPS/CONOPS Sub-TG) was held on 11-12 July, 1989. The meeting took the form of a symposium at the Naval Aerospace Medical Research Laboratory, Pensacola, Florida. Twelve speakers provided overviews of SUSOPS/CONOPS issues and described current research efforts. This document provides a synopsis and abstracts of the presentations, consistent with the goals of the subgroup to provide a mechanism for information exchange, enhance coordination among government agencies, identify technology gaps and requirements, and encourage technical interaction.

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SUMMARY PAGE

OVERVIEW

The 9th semiannual meeting of the Sustained/Continuous Operations Subgroup of the Department of Defense Human Factors Engineering Technical Group (DOD HFE SUSOPS/CONOPS Sub-TG) was held on 11-12 July, 1989. The meeting took the form of a symposium at the Naval Aerospace Medical Research Laboratory, Pensacola, Florida. Twelve speakers provided overviews of SUSOPS/CONOPS issues and described current research efforts. This document provides a synopsis and abstracts of the presentations, consistent with the goals of the subgroup to provide a mechanism for information exchange, enhance coordination among government agencies, identify technology gaps and requirements, and encourage technical interaction.

Acknowledgments

The DOD HFE SUSOPS/CONOPS Sub-TG thanks the Naval Medical Research and Development Command and the Naval Aerospace Medical Research Laboratory for providing support for the meeting and this publication.

INTRODUCTION

The Department of Defense (DOD) Human Factors Engineering Sustained/ Continuous Operations Technical Subgroup (DOD HFE SUSOPS/CONOPS Sub-TG) held its 9th semiannual meeting on 11-12 July, 1989. The subgroup defines SUSOPS/ CONOPS as work schedules requiring steady productivity over a period of time beyond a normal duty cycle, usually leading to fatigue and/or sleep deprivation. Topics addressed by the subgroup include work/rest schedules, circadian rhythmicity, alertness and sleep deprivation, sleep discipline, fatigue, pharmacological intervention, rapid deployment demands, and sustained performance with unique equipment and in unique environments. The major goals of the subgroup are to a) provide a mechanism for information exchange in these areas, b) enhance coordination among government agencies, c) identify technology gaps and requirements, and d) encourage technical interaction.

The 9th semiannual meeting was in the form of a symposium at the Naval Aerospace Medical Research Laboratory, Pensacola, Florida. The presentations are listed in the agenda in Section A. Abstracts of the presentations are in Section B. Section C consists of a meeting attendance list. The subgroup charter is in Section D. Section E is a reprint of a recent review paper by LTC Gerald Krueger published in Work and Stress. Section F provides an address form for those interested in attending the subgroup meeting and receiving future SUSOPS announcements and publications.

SYNOPSIS OF PRESENTATIONS

Several participants discussed a variety of issues that impact on SUSOPS/ CONOPS research. LTC Gerald Krueger of the Army Aeromedical Research Laboratory provided definitions of terms, summarized and described performance variables important in SUSOPS/CONOPS conditions, and compared the effectiveness of several work/rest cycles. Asserting that sleep loss is the most important concern in SUSOPS, he finished by discussing several strategies that may serve to reduce the associated decline in performance. Section E contains a reprint of a paper by LTC Krueger that reviews the issues involved in SUSOPS/CONOPS research in greater detail.

Dr. Paul Naitoh of the Naval Health Research Center (NHRC) further examined the issue of sleep loss in both industrial and military settings. He described different types of sleep, the ways to obtain core sleep, and the problems associated with sleep inertia after premature awakening. He argued for the consideration of sleep logistics in mission planning and a change in command/management attitude that would allow the use of ultra-short naps (< 30 min) to boost performance.

Dr. Tamsin Kelly, also of NHRC, presented an overview of five SUSOPS-related research programs at that laboratory. The first of these efforts is an investigation of the effects of several sleeping agents, as well as caffeine, on performance. The unique demands of Special Forces missions are being addressed in a second series of studies in which physiological correlates of training have been identified. Several pharmacological interventions, in addition to diet manipulation, are being investigated. Work is also underway in a third program on the development of a model to predict performance degradation during cold weather SUSOPS. A fourth series of studies has begun to examine the effects on physical and cognitive performance of chemical defense clothing, pretreatment drugs, and antidotes. Cognitive performance is being assessed with the Uniform Tri-services Committee Performance Assessment Battery (UTC-PAB). Finally, a new study is investigating the possible benefits of bright light on mood, performance, and physiology during night shift work.

Some preliminary results on this issue of the effect of bright light on plasma melatonin and cognitive performance were reported by Dr. Jon French of the Crew Performance Laboratory of the USAF School of Aerospace Medicine. The early results suggest that bright-light introduction during a 30-h testing session briefly decreased reaction time and errors on the Complex Cognitive Assessment Battery (CCAB) and Walter Reed subset of the UTC-PAB (WRPAB). The light was also associated with elevated oral temperature, implying melatonin suppression. Dr. French pointed out that, if these early results hold, the use of bright lights may be a means of improving the vigilance of video display operators and, along with melatonin ingestion, allow for phase-shifting of workers.

A current thrust in SUSOPS research is the investigation of stimulants as a countermeasure to performance degradation. Representatives from four different laboratories described research programs in this area. MAJ David Penetar of the Walter Reed Army Institute of Research described a 60-h sleep deprivation study in which cognitive (PAB), physiological, and sleep-latency measures, as well as subjective ratings, were obtained. Biochemical assays were also performed. One of three drugs (d-amphetamine, nicotine, or l-deprenyl) was administered after 48 h in one of three doses. Only d-amphetamine (5, 10, or 20 mg *p.o.*) resulted in a dose-related increase in sleep latency. Reported vigor and accuracy on the serial add/subtract and logical reasoning tasks of the PAB also increased. The results were interpreted as promising evidence of the ability of amphetamines to restore alertness and mood and return certain aspects of mental performance to pre-sleep-deprived levels.

Dr. Charles DeJohn described the SUSOPS research program at the Naval Aerospace Medical Research Laboratory (NAMRL). This program is also addressing the possible use of stimulants, in this case during a 60-h flight SUSOP. Data collection is underway using a computerized battery of cognitive (CCAB, WRPAB), visual, auditory, physiological, and subjective measures to examine the effects of a single 10-mg oral dose of methamphetamine. The scenario simulates that of carrier-based attack aircraft: 9 h planning, 4 h rest, 14 h mission. The cycle is repeated after 6 h rest. The stimulant is administered at 50 h and 40 min into the study.

LCDR Dennis Reeves, also of NAMRL, presented some preliminary findings on the CCAB and WRPAB in the above study. He reported no significant differences on the CCAB between planning sessions 1 and 2, however, 10 mg of methamphetamine was associated with improved performance on the four-choice reaction time and logical reasoning tasks of the WRPAB. These results were accompanied by increased feelings of alertness on the Stanford Sleep Scale. Grip strength decreased during the 14-h test sessions but improved following drug administration. Quantitative analyses are currently underway, and similar studies with higher dosage levels will follow.

Dr. Mary Winsborough of ARE/ALVERSTOKE in the United Kingdom presented the results of a Micro SAINT model she developed on the preceding SUSOPS scenario while at NAMRL. The model was used to determine where in the scenario to administer the drug. Unfortunately, her abstract was not received before the publication deadline.

Dr. Didier LaGarde described stimulant research he is conducting at the CES de Biologie et Medecine du Sport, CES de Medecine Aeronautique et Spatiale, CERMA, Paris. Initial experiments with rhesus monkeys identified Modafinil as a promising psychostimulant. A 22.5-mg/kg dose resulted in improved performance with no reported side effects. Administration to humans who were 36-h sleep-deprived also showed positive results. In collaboration with NAMRL, future plans include further human experimentation using the flight SUSOP scenario described above and computerized French versions of the WRPAB and AGARD STRES batteries.

Two speakers concentrated on research issues. LT David Kobus of NHRC adopted a global approach. He emphasized the need for relevant operational studies in SUSOPS research. He described a recent data collection expedition to the Persian Gulf and showed a videotape that clearly demonstrated the physical and mental challenges facing the military personnel stationed there. He pointed out some important differences between the laboratory and operational environments that need to be addressed more explicitly. These include the extreme monotony and boredom present for long periods during SUSOPS, and the lack of knowledge of task duration or completion point in real operations. Further, the performance data indicate that the introduction of laboratory tests (e.g., the PAB) in operational situations may provide a desirable break in the routine to the subjects, resulting in high and stable performance over time, thereby undermining the test's sensitivity. LT Kobus argued for greater use of operationally relevant tasks to evaluate performance in operational settings.

Dr. Harvey Babkoff of Bar-Ilan University, Israel, and NHRC adopted a different approach, focusing on a methodological issue relevant to sleep-deprivation studies. He explored the distinction between response lapses, accuracy, and reaction time by presenting data from a visual shape discrimination task. He offered an alternative approach that uses the response lapse as an index of the sleepiness state of the individual. It is, therefore, a measure of general performance. Accuracy and response time remain measures of specific task performance. They are related to lapses as dependent variables are to an independent variable. Combined performance measures (e.g., throughput) were criticized as being of limited utility and ambiguous with respect to cognitive function. Dr. Babkoff argued for the separate reporting of all dependent measures, not just combined ones.

Finally, LTC John Lombardi of the U.S. Army Chemical School described the Combined Arms in a Nuclear/Chemical Environment (CANE) research program being conducted by the Army. The study assesses how well combat and support units can perform in extended (72-96 h) operations in the nuclear/chemical environment. The operations are force-on-force exercises involving a mechanized infantry platoon (CANE I), tank heavy company team (CANE IIA), and battalion task force (CANE IIB). In his classified briefing, LTC Lombardi also showed a videotape of the lessons learned in CANE II. Future CANE evaluations are planned for light forces, aviation, and air defense.

SECTION A

SUSTAINED/CONTINUOUS OPERATIONS SUBGROUP OF THE DOD HFE TG
Naval Aerospace Medical Research Laboratory, Pensacola, Florida

AGENDA

11 July 1989

0830-0845	WELCOME ABOARD Captain James A. Brady Commanding Officer, Naval Aerospace Medical Research Laboratory
0845-0900	INTRODUCTORY REMARKS LCDR Dennis L. Reeves Chair, Sustained/Continuous Operations Subgroup of the DOD HFE TG
0900-1000	CONOPS AND SUSTAINED PERFORMANCE: A REVIEW OF THE ISSUES LTC Gerald P. Krueger U.S. Army Aeromedical Research Laboratory
1000-1015	BREAK
1015-1045	REVERSAL OF SLEEP DEPRIVATION EFFECTS BY STIMULANT DRUGS MAJ David M. Penetar Walter Reed Army Institute of Research
1045-1130	THE INFLUENCE OF BROAD SPECTRUM ILLUMINATION ON CIRCADIAN NEUROENDOCRINE RESPONSES AND PERFORMANCE Dr. Jon French USAF School of Aerospace Medicine
1130-1300	LUNCH
1300-1345	SUSTAINED OPERATIONS RESEARCH AT CERMA-LCBA Dr. Didier LaGarde CES de Medecine Aeronautique et spatiale, CERMA, France
1345-1400	BREAK
1400-1430	SUSTAINED FLIGHT OPERATIONS RESEARCH AT NAMRL Dr. Charles A. DeJohn Naval Aerospace Medical Research Laboratory
1430-1500	THE EFFECTS OF A SUSTAINED FLIGHT OPERATIONS SCENARIO ON COGNITIVE PERFORMANCE: PRELIMINARY RESULTS LCDR Dennis L. Reeves & Mr. Peter Dahms Naval Aerospace Medical Research Laboratory
1500-1530	APPLICATION OF MICRO SAINT MODELING FOR DEVELOPING COUNTERMEASURES FOR SUSTAINED FLIGHT OPERATIONS Dr. Mary M. Winsborough ARE/ALVERSTOKE, England
1530-1545	DISCUSSION

12 July 1989

0900-1000	THE ULTRA SHORT SLEEP IN ACTION: RESEARCH ISSUES AND OPERATIONAL APPLICATIONS Dr. Paul Naitoh Naval Health Research Center
1000-1030	OVERVIEW: FACILITIES AND RESEARCH CAPABILITIES OF THE NHRC SLEEP RESEARCH DEPARTMENT AND ASSOCIATED LABORATORIES Dr. Tamsin Kelly Naval Health Research Center
1030-1045	BREAK
1045-1130	SLEEP DEPRIVATION AND COGNITIVE PERFORMACE: RESPONSE LAPSES VS ACCURACY AND REACTION TIME Dr. Harvey Babkoff Bar-Ilan University, Israel
1130-1300	LUNCH
1300-1345	EFFECTS OF SHIPBOARD SUSTAINED OPERATIONS: PERSIAN GULF 1988 (Issues of laboratory vs. field research) LT David A. Kobus Naval Health Research Center
1345-1400	BREAK
1400-1500	CANE II: LESSONS LEARNED (Classified Briefing) LTC Jack Lombardi US Army Chemical School
1500-1600	TOUR OF BUILDING 1811

SECTION B

Presentation 1:	LTC Gerald P. Krueger U.S. Army Aeromedical Research Laboratory
Presentation 2:	MAJ David M. Penetar Walter Reed Army Institute of Research
Presentation 3:	Dr. Jon French USAF School of Aerospace Medicine
Presentation 4:	Dr. Didier LaGarde CES de Medecine Aeronautique et spatiale, CERMA France
Presentation 5:	Dr. Charles A. DeJohn Naval Aerospace Medical Research Laboratory
Presentation 6:	LCDR Dennis L. Reeves and Mr. Peter Dahms Naval Aerospace Medical Research Laboratory
Presentation 7:	Dr. Mary M. Winsborough ARE/ALVERSTOKE, England
Presentation 8:	Dr. Paul Naitoh Naval Health Research Center
Presentation 9:	Dr. Tamsin Kelly Naval Health Research Center
Presentation 10:	Dr. Harvey Babkoff Bar-Ilan University, Israel
Presentation 11:	LT David A. Kobus Naval Health Research Center
Presentation 12:	LTC Jack Lombardi U.S. Army Chemical School

PRESENTATION 1

SUSTAINED WORK, FATIGUE, SLEEP LOSS, AND PERFORMANCE: A REVIEW OF THE ISSUES

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BACKGROUND

The Sustained Operations/Continuous Operations (SUSOPS/CONOPS) Subgroup assembled a document repository of scientific and technical reports (including 582 SUSOPS/CONOPS references) covering the years 1940-1989. Upon review of that literature (Krueger, 1989), key variables in eight major subject areas were deemed to be particularly pertinent to our Department of Defense multidisciplinary, multi-laboratory research programs. This presentation summarized the key research variables on sustained human performance in laboratory and field studies of soldiers, sailors, and airmen during CONOPS/SUSOPS.

CONOPS/SUSOPS DEFINITIONS

Continuous Operations (CONOPS) imply an uninterrupted schedule of nonstop activity employing individual workers on regularly scheduled "normal shift lengths of 7-12 h," but, who are then relieved by others while the overall operation continues around-the-clock. Workers later return to the job as scheduled, hopefully after adequate rest and sleep. Practical experience in military operations indicates rest and sleep obtained close to the job site are often intermittent, broken, and unrestorative.

Many individuals work on shifts longer that 12 h, performing at close to a nonstop rate as long as they can. These unusually long work stints are referred to as sustained operations (SUSOPS). Usually they are not planned, but the work must be continued until a goal is reached, and time on the job lasts long enough for workers to experience fatigue and sleep loss, leading to reduced performance, efficiency, and effectiveness.

CONOPS/SUSOPS PERFORMANCE VARIABLES

A number of factors associated with sustained work affect the psychological and physiological condition of workers and moderate job performance during SUSOPS. They include:

Characteristics of the Job, Work Tasks

Jobs differ in the amount of prolonged uninterrupted activity, constant attention, and stamina required. Vigilance and attention become progressively less efficient, the number of correct detections drops, and response time to correct detections rises as vigilance time continues. Performance on machine-paced tasks, more so than worker-controlled tasks, is adversely affected by small amounts of sleep loss leading to errors of omission. Sustained intense physical effort leads to muscle fatigue and eventual failure to perform.

Sustained cognitive work leads to feelings of fatigue or weariness and burn out. Sleep loss hastens the onset of, and increases the frequency of, cognitive performance decrements, especially on attention demanding vigilance tasks.

Rhythmic Variations in Worker Performance

Workers exhibit various predictable physiological and behavioral circadian rhythms. Alertness declines most as body temperature decreases to its lowest level from 0300-0600 and to a lesser extent from 1600-1800. Worker performance not only varies with time-of-day but also interacts with work schedule and may result in different time-of-day effects for different tasks. Since workers find problems overriding circadian factors when switching between day and night schedules, CONOPS planners must evaluate whether or not to employ teams of "night fighters" alternately with the day time combatants.

Weariness, Tiredness, and Fatigue

Physical fatigue is the temporary loss of power to respond--the muscular tiredness one feels after sustained vigorous exercise. Mental fatigue is the subjective feeling of weariness that accompanies repeated performance of nonphysical tasks and may involve monotony and boredom, accentuated by tiredness and drowsiness associated with sleep loss. Fatigue likely leads to "aversion to effort."

Work Rest Breaks, Work Shifts, and Work/Rest Cycles

Work breaks, pauses, and split shifts help overcome acute fatigue effects and relieve boredom. Depending upon the availability of sufficient numbers of workers to conduct CONOPS, numerous alternative shift schedules are possible. Each presents its own advantages and disadvantages in terms of amounts of productivity, efficiency, amounts of rest and sleep permitted, and worker preferences.

Effects of Sleep Loss

When workers perform for extended periods and lose sleep, the accumulating sleep loss degrades performance; frequently workers maintain accuracy but perform slower, thereby accomplishing less usable work over time. The "lapse hypothesis" suggests, with sleep loss, signals are missed intermittently and more so as sleep loss continues.

Naps and their Effects on Sustained Performance

At least 4-5 h of uninterrupted sleep should be taken every 24 h to prevent impaired performance. Shorter, additional sleep periods (naps) should also be used in a program of sleep management during military operations to help maintain performance and mood. Sleep inertia upon awakening (grogginess) may sometimes be expected.

Pharmacological Intervention

Some research indicates sleep induced by hypnotics in "off-duty" periods may acceptably restore performance alertness, but there is not unanimity as to which sleep aids are acceptable. In select circumstances, stimulants can be used to maintain alertness to meet extended performance demands, but most of them have distortive effects, present safety concerns, and produce rebound effects. More quality behavioral pharmacological research needs to be done.

Other Factors

Worker performance during SUSOPS is influenced by the interaction of prior rest quantity, physical fitness, endurance, environmental conditions, number of sustained work episodes, time of day of performance, task type, workload, and motivation, among other factors.

Psychological and physiological models of sustained performance must account for continuing operating demands of long work stints, fatigue, sleep loss, circadian rhythms, et cetera, and delineate performance predictions as functions of tasks type, account for scheduling of rest breaks, levels of motivation and other intervening variables.

STRATEGIES FOR SUSTAINING MILITARY PERFORMANCE

- o Get proper personnel staffing for CONOPS; divide workload.
- o Cross-train personnel; overlearn on select tasks.
- o Create, train, and accommodate "night fighter" teams.
- o Physical fitness, nutrition, lighten soldier loads.
- o Plan for CONOPS/SUSOPS.
- o Develop and adhere to sleep management plan.
- o Rest/sleep/nap when you safely can.
- o Develop common courtesy to others trying to sleep.

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PRESENTATION 2

REVERSAL OF SLEEP DEPRIVATION EFFECTS BY STIMULANT DRUGS

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(301) 427-5521 or AV 291-5521

OBJECTIVES

Laboratory studies on the neurobiology of arousal and alertness. Assessment of changes in physiology, mood, and cognitive performance during periods of sleep deprivation.

APPROACH

Healthy, young adult male volunteers undergo 60 h of total sleep deprivation with periodic monitoring of vital signs, mood, and electroencephalographic assessment of alertness. Additionally, cognitive performance is assessed through a multiple-task computerized performance assessment battery. After 48 h of sleep deprivation, stimulant drugs are given, and the subjects are tested and monitored for an additional 12 h. Drugs tested include the prototypical stimulant d-amphetamine (5, 10, and 20 mg *p.o.*), nicotine (a cholinergic agonist: 0.52, 0.78, 1.05-mg/70 kg *i.v.*), and 1-deprenyl (a new monoamine oxidase inhibitor antidepressant: 10, 20, 30 mg *p.o.*). Experiments are conducted double-blind.

RESULTS

Amphetamine produced dose-related reversals of sleep-deprivation effects. Alertness, as measured by the latency to sleep, returned to well-rested (day 1 non sleep-deprived) conditions for 2 h following the 20-mg dose. Latencies remained significantly longer than sleep-deprived day-3 placebo condition for 7 h following the 20-mg dose and for 3 h following the 10-mg dose. Self-ratings of vigor and fatigue as measured by the Profile of Mood States questionnaire tended to follow the pattern of sleep latency. Two measures of cognitive performance were sensitive to amphetamine effects. Percentage accuracy on an attentional arithmetic task returned to pre sleep-deprived conditions following the 20-mg dose and remained so for 10 h. A logical reasoning task showed a gradual improvement, peaking at 7 h after drug. Nicotine had no significant effects on our measures. The 1-deprenyl effects on sleep latencies and cognitive performances were modest in comparison to amphetamine and non significant despite subjective reports of alert feelings.

FUTURE OBJECTIVES

Continued use of the paradigm to assess additional drugs and medications for alerting benefits. Caffeine will be studied beginning in early 1990. Ongoing protocol is assessing the biochemical basis of amphetamine's effects through the use of a tyrosine hydroxylase inhibitor (alpha methyl para tyrosine, trade name Demser).

PRESENTATION 3

THE INFLUENCE OF BROAD-SPECTRUM ILLUMINATION ON CIRCADIAN NEUROENDOCRINE RESPONSE AND PERFORMANCE

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Crew Performance Lababoratory
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Brooks AFB, TX 78235-5301
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OBJECTIVES

Plasma levels of the pineal hormone melatonin are greatest during the sleep phase of the vertebrate circadian cycle. Orally administered melatonin is associated with sleepiness and increased measures of fatigue. Melatonin, therefore, may act as a natural fatiguing agent that promotes sleep. Recently, it has been shown that melatonin levels can be acutely suppressed by bright, white light in mammals including man. If increased light intensity, holding the spectral composition of light constant, can control the levels of circulating melatonin, then it may delay the sleep stage of the circadian cycle and attenuate fatigue degraded performance. The objective of this project was to assess the effects produced by wide spectrum, bright illumination on plasma melatonin and to determine if this treatment could reduce fatigue and enhance performance.

APPROACH

A counter-balanced, within-subjects design was used to compare nine male subjects exposed to dim (100 lux) and bright (3000 lux) conditions. Singly blinded experimental conditions were masked from the subjects by presenting the dim light as a "focused" light condition and the bright light as a "diffuse" light condition. During both conditions, performance scores on selected tests from the CCAB and WRPAB were obtained every 2 h throughout the 30-h testing session. Beginning at 0700, subjects were first stabilized on the performance measures under dim light conditions. Then at 1800, the light treatment (either dim or bright) began and lasted until 0800 the next day. Finally, dim light conditions were reinstated to determine the duration of any bright-light effects until 1300 when the session concluded. Frontal and occipital EEG, eyeblink, and ECG were recorded immediately following each performance trial. A blood sample and a saliva sample were obtained for melatonin, cortisol, and proclactin assays immediately following each electrophysiological sample as was an oral temperature sample. Subjects were allowed 2 weeks to recover before exposure to the second light condition. Sleep patterns during this period were monitored to ensure recovery.

RESULTS AND FUTURE OBJECTIVES

The results of this study are still being considered. Oral temperature inversely parallels melatonin levels. In lieu of the impending biochemical assays, oral temperature levels were elevated in the bright-light group independent of ambient temperature, particularly at the 0130 and 0330 sample points, suggesting melatonin suppression was accomplished. Preliminary analyses suggest that, in most of the tests considered, bright-light treatment improved reaction time while reducing the number of errors, particularly at the 0400 and 0600 sample points. The duration of these effects was minimal as performance rapidly deteriorated when the bright-light treatment ended.

At least two objectives of the present study would have immediate applicability if borne out by analysis. The first of these would be to suggest that during extended duty cycles, such as those for radar or console operators, bright lights may be used to heighten the level of alertness and improve performance otherwise susceptible to fatigue. Secondly, meaningful correlations between salivary and plasma melatonin might lead to the development of a simple non-invasive means to determine the current position of the circadian cycle. Future objectives of this type of research may lead to the use of lights and possibly melatonin ingestion to rapidly phase advance shift workers to a new schedule or to alleviate the fatiguing effects of travel across time zones.

PRESENTATION 4

PHARMACOLOGICAL STUDIES RELATIVE TO THE CONTROL OF SLEEP-WAKE CYCLE AT THE CERMA-LCBA

Dr. Didier LaGarde
Medical Officer, CES de Biologie et Medecine du Sport
CES de Medecine Aeronautique et spatiale, CERMA-LCBA
5BIS, Avenue de la Porte de Sevres
75731 Paris 15 Air Cedex, France
Overseas Number

OBJECTIVES

To study disturbances of sleep-wake cycle during sustained and continuous operations two approaches are made. First, a physiological approach: management of wakefulness. personal instruction, training for stressful situations, and optimal utilization of sleeping times under operational conditions. Second, a pharmacoligical approach: sleep induction or efficient maintenance of wakefulness.

APPROACH

Utilization of the molecule evaluation schedule in the rhesus monkeys.

Phase I: Evaluation of molecule value (night actography/acute behavioral toxicity).

Phase II: Evaluation of efficiency: EEG sleep.

Phase III: Evaluation of innocuity: Behavior (operant conditioning, social behavior), vegetative parameters.

Phase IV: Testing for tolerance or dependency cues.

RESULTS

One of the 10 psychostimulants studied has yielded good results: Modafinil. Insomnia of 7-10 h with administration of 22.5 mg/kg without side effects at efficient dose.

FUTURE OBJECTIVES

Experimentation in humans to reduce effects of sleep deprivation on physical and psychometric performance.

PRESENTATION 5

SUSTAINED FLIGHT OPERATIONS RESEARCH AT THE NAVAL AEROSPACE MEDICAL RESEARCH LABORATORY

Dr. Charles A. DeJohn
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OBJECTIVES

To select and evaluate pharmacological enhancement agents for possible use during sustained naval flight operations (SUSOPS). To evaluate the effects of the agents on performance. To develop fleet guidelines to implement the use of pharmacological enhancement agents during SUSOPS.

APPROACH

A dose-response, performance assessment study in a controlled laboratory environment is underway. A simulated carrier-based attack aircraft scenario, including 9 h of mission planning, 4 h of crew rest, and a 14-h simulated flight mission is being followed. After 6 h of crew rest between missions, the cycle is repeated. Two starting times for the scenario are used to account for time-of-day effects. One is at 0600, and the other is at 1800. The effects of 10-, 15-, and 20-mg oral doses of methamphetamine on cognitive, visual, acoustic, and physiological performance, and psychiatric status will be evaluated.

RESULTS AND FUTURE OBJECTIVES

At the present time, data collection using the 10-mg dose and the 0600 starting time is underway but is incomplete. A joint French-American study is beginning, to compare the effectiveness of methamphetamine with a new French stimulant (Modofinil).

PRESENTATION 6

SUSTAINED FLIGHT OPERATIONS RESEARCH AT NAMRL: PRELIMINARY RESULTS

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Overseas Number

INTRODUCTION

Long-range flight operations and miltiple-day missions are currently operational realities within a variety of Navy aviation communities. As a result, problems associated with fatigue, desynchronizationn of biological rhythms, and fragmented sleep are no longer restricted to shipboard and infantry operations but are now of concern for Navy aircrews as well. In response to this problem, the Naval Aerospace Medical Research Laboratory (NAMRL) is conducting research that is desinged to develop performance-degradation countermeasures for sustained flight operations. This report presents results derived from a preliminary analysis of data from two NAMRL SUSOPS programs. One program is designed to develop nonpharmacological countermeasures, and the other (described in the preceding paper by Dr. C. DeJohn) is designed to develop strategies and guidelines for possible use of pharmacological countermeasures.

METHODS

Two sets of 12 Navy aviation students were trained on a battery of tests over a 5-day period and then were formally tested on this same battery during a 60-h continuous/sustained operations protocol that involved the following work/rest schedule:

9 h continuous performance with breaks
4 h for sleep or rest
14 h of sustained performance (no breaks)

6 h for sleep or rest

9 h continuous performance with breaks
4 h for sleep or rest
14 h of sustained performance (no breaks)

One group served as a "no-countermeasure" control, and the other group was administered a capsule containing approximately 10-mg methamphetamine during the second 14-h schedule. The second group will also contain 12 placebo control subjects, however, these data are still being collected at this time. As stated by Dr. DeJohn, the test battery is multidisciplinary by design.

Analyses of these data to date are descriptive and have focused on tests derived from two automated cognitive assessment batteries: the Complex Cognitive Assessment Battery (CCAB) and the Walter Reed Performance Assessment Battery (WRPAB). In addition, we have conducted a preliminary analysis of the grip-strength test data.

The CCAB tests included the Tower Puzzle, Following Directions, Route Planning, and Numbers and Words. These tests were designed to provide a means for evaluating performance on tasks that require high-level, complex cognitive skills. These include attention to detail, memory retrieval, time sharing, planning, decision making, and problem solving. The CCAB was administered three times during the 9-h continuous work periods. It was not administered during the 14-h sustained work periods. The WRPAB was administered 20 times in all during the experiment and was administered during both 9- and 14-h work periods. This specific subset included Mood Scale II, the Manikin test, Logical Reasoning, Matrix I, Time Wall, Serial Addition and Subtraction, four-choice Serial Reaction Time, Interval Production, and Stanford Sleep Scale. All cognitive tests were administered using Zenith Z-248 (IBM-AT compatible) microcomputers. The grip-strength test was administered only during the 14-h work periods.

RESULTS AND DISCUSSION

Results from the CCAB and WRPAB indicated that stability was attained during the training week. The CCAB performance remained stable throughout the formal testing sessions. We interpreted this to indicate that the rest periods that preceded the 9-h work periods, and the scheduled breaks, were sufficient to counter potential fatigue effects. Hence, the CCAB results indicated an absence of significant differences over sessions.

As stated above, the WRPAB was admistered during all work periods. This allowed an analysis of both fatigue and methamphetamine. Data analysis here consisted of inspection of group means from each test session. The actual measure was a throughput variable which is a combination of accuracy and response times. Visual inspection of the data revealed a marked consistency of performance between the two groups of subjects, up to the point that the countermeasure was administered. Major fatigue and "circadian trough" effects were indicated by a drop in performance that occured near the end of the first 14 h work schedule (about 03:50 h). This result was anticipated because the subjects had been working at their computers throughout the night without breaks or meals.

The control versus methamphetamine group comparison revealed differential effects of the countermeasure administration. With respect to the performance tests, methamphetamine appeared to enhance performance on the four-choice reaction time and the logical reasoning tests. This between-groups comparison revealed no performance differences associated with the Manikin, Serial Add/ Subtract, or Matrix 1 tests. In addition, the subjective report from the

Sleep Scale indicated a major reduction of fatigue following meth-amphetamine administration, as expected. We did not attempt an analvsis of the Mood Scale II data because of significant initial differences between the groups on this test.

Grip-strength data revealed a general weakening over the 14-h test sessions. This trend was dramatically reversed following methamphetamine administration.

In conclusion of this paper, we feel that it is important to restate that the studies cited are presently ongoing, and this report is of preliminary results and is based on qualitative analyses. Quantitative analyses will follow on completion of the data collection. It will be interesting to see if our observation of differential effects of meth-amphetamine on cognitive performance in this protocol is confirmed or refuted by statistical scrutiny.

PRESENTATION 7

APPLICATION OF MICRO SAINT MODELING FOR DEVELOPING COUNTERMEASURES FOR SUSTAINED FLIGHT OPERATIONS

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Dr. Winsborough's paper was not received in time for publication.

PRESENTATION 8

THE ULTRA-SHORT SLEEP IN ACTION: RESEARCH ISSUES AND OPERATIONAL APPLICATIONS

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OBJECTIVES

Review the current practices of sleep management in industrial and military settings to expound the merits of ultra-short sleep at work sites for increasing operational safety and productivity. Develop guidance for ultra-short sleep in field operations. Ultra-short sleep refers to a duration of sleep of less than 30 min.

APPROACH

Irregular and/or sustained work schedules inevitably increase fatigue and sleepiness, resulting in lowered vigilance even in periods of involuntary sleep by sheer exhaustion. Sleep of exhaustion occurs on the job, and sudden premature awakenings from it creates a post-sleep period characterized by profound performance degradation, known as sleep inertia. Sleep management or sleep logistics suggests prevention of such sleep incidents by providing guidance on how best to maximize the recuperative power of ultra short sleep periods, each lasting from 5 to 20 min.

Sleep logistics helps obtain a more realistic estimate of the manpower requirement in a sustained operation. Sleep logistics provides none-injury loss of manpower due to excessive fatigue and sleepiness. It has as much operational utility to a successful completion of a mission as considering the logistics of food, ammunition, and fuel supplies. Sleep management develops the guidelines on estimating the loss of manpower under irregular and/or sustained work environments by means of a mathematical model based on job performance data.

RESULTS AND FUTURE OBJECTIVES

The principles of sleep management are available in the NHRC Report No. 86-22, Sleep Management in Sustained Operations: User's Guide. A future User's Guide will include the guidelines on the use of pharmacological agents in the context of sleep management.

The nature of short sleep (napping) is discussed in two chapters, one by Stampi and the other by Naitoh and Angus in a book, Sleep and Alertness (D.F. Dinges and R.J. Broughton, Eds.), Raven Press, 1989. A new work unit at the NHRC on ultra-short sleep will clarify efficacy of very short but many periods of sleep, each lasting 5, 10, 15, or 20 min, in maintaining cognitive performance during 64 h of a sustained operation.

The development of a mathematical sleep logistics model represents cooperative efforts between the Naval Aerospace Medical Research Laboratory and NHRC.

PRESENTATION 9

OVERVIEW: FACILITIES AND RESEARCH CAPABILITIES OF THE NHRC SLEEP RESEARCH DEPARTMENT AND ASSOCIATED LABORATORIES

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PROGRAM 1. *Effects of Pharmacological Agents on Individual Differences in Performance.*

Objectives

Evaluate and determine mechanisms of the physiological and cognitive effects of pharmacological agents on individual differences in performance.

Approach

Laboratory studies employing computer controlled cognitive testing, polysomnography, and evoked potentials are used to evaluate effects and the mechanisms of action of pharmacological agents.

Results and Future Objectives

Benzodiazepines and tryptophan have been investigated as possible sleeping aids for use in military situations. While next-day sleepiness from benzodiazepines can be countered with caffeine, triazolam impairs arousability and performance during the period of drug action and can cause anterograde amnesia, making it a questionable agent, particularly in the sustained operation context where the sleep period duration may be difficult to predict. Tryptophan can decrease sleep latency and does not have these benzodiazepine drawbacks. A study of the mechanism of action of caffeine and its effects on individual differences in performance when used as a stimulant during sustained operations is in progress. The effects on prolonged cold-water immersion on serum levels of beta-endorphins and the relationship of these levels to physiological and cognitive changes are to be investigated in FY 90 as a preliminary step to possible future studies on the use of opiate antagonists during cold-water diving missions or during treatment of hypothermia related to missions involving any sort of prolonged exposure to cold.

PROGRAM 2. *Biomedical Enhancement of Mission Performance of Special Forces Personnel.*

Objectives

Evaluate the demands of Special Warfare missions, the characteristics of Special Forces personnel, and the risks and benefits of performance enhancement interventions.

Approach

Mission demands are being evaluated both during field training missions and in laboratory simulations. Special Forces personnel have been characterized in laboratory studies. Performance enhancement interventions are being evaluated in laboratory testing. A cold immersion tank has been set up for the controlled laboratory studies, and equipment allowing monitoring of extensive physiological data during both laboratory and field diving studies has been developed.

Results and Future Objectives

The physical, enviornmental, and psychological demands of various types of special forces missions have been characterized. Data collection during sessions in the Swimmer Delivery Vehicle (SDV) Trainer are ongoing. Special forces personnel, both trainees and those who have completed training, have been profiled in great detail, both physiologically and phychologically. Serum markers of training effects have been discovered, which may be useful in preventing injury or determining when personnel should be scheduled for a given mission. Aqueous glycerol solution has been found to enhance plasma volume retention during cold-water diving. A high-fat, low-carbohydrate diet has been found to promote endurance in animals and is currently being evaluated in human subjects. Methylphenidate and pemoline are being tested as possible alternatives to amphetamines for use during sustained operations. A follow-up study with methylphenidate will examine the interactions of stimulant effects with those of prolonged cold-water immersion. Another cold-water diving simulation study to start up in FY90 will investigate the physiological, psychological, and cognitive performance effects of pseudoephedrine and terfenadine during prolonged cold-water immersion.

PROGRAM 3. *Cold-Related Combat Decrements.*

Objectives

Identify cold-related combat task performance degradations during arctic SUSOPS and develop a predictive model of performance in cold enviornments.

Approach

Data are currently being collected on the physiological, psychological, biochemical, and performance degradations during cold-weather SUSOPS training missions in U.S. Marines. Development of a model to predict performance in cold environments is underway.

ROGRAM 4. *The Impact of Chemical Defense Measures on Sustained Military Operations.*

Objectives

Describe the effects of chemical-defense clothing and antidotes and pretreatment drugs on physiological and psychological measures and physical cognitive performance during SUSOPS.

Approach

A series of laboratory studies employing the Unified Tri-service Cognitive Performance Assessment Battery (PAB) have investigated the effects of chemical protective gear. Field studies are underway.

Results and Future Objectives

Technical reports have been published on the first three phases of this program. Gas masks and full MOPP4 gear have been found to have significant but acceptable effects on physiological and cognitive measures when worn for up to 12 h during nonexercise activities. Data collection on a study of the effects of MOPP4 gear on performance of prolonged intermittant exercise while carrying up to 75% of body weight has been completed, and analysis is underway. A field study of the effects of MOPP4 gear during SUSOPS exercises is in progress. Performance as measured by the PAB is to be correlated with data from operational tasks, and a Micro SAINT model will be developed.

PROGRAM 5. *Bright Light Amelioration of Shift Work.*

Objectives

Evaluate the possible benefits and the underlying mechanisms of using bright-light treatment during night shift work.

Approach

A VA/DOD cooperative laboratory study is examing the effects of 3 h of bright-light exposure at different phases of the circadian cycle on mood, performance, melatonin, cortisol, prolactin, and core temperature during night shift work.

Results and Future Objectives

This is a new program. The first study is underway. If benefits are demonstrated, applications in the field will be pursued.

PRESENTATION 10

SLEEP DEPRIVATION AND COGNITIVE PERFORMANCE: RESPONSE LAPSES VERSUS ACCURACY AND RESPONSE TIMES

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One of the more influential hypotheses to explain the effects of sleep deprivation on performance is the lapse hypothesis (1-3), whose major point is that sleep deprivation leads to increased unevenness of performance rather than to gradual performance decrement. Thus, "gaps," "blocks," or "lapses" in performance occur with increasing frequency over time. Between blocks or lapses, performance can be maintained close to the normal level. The lapse thus represents a time-out between responses.

Traditionally, response lapses have been divided into two categories, one related to response speed, the other to errors of omission. In paced (or experimenter-controlled) tasks, the stimulus is present for a short time only, and the response must be made within a brief, defined interval. A lapse may, therefore, coincide with the appearance of the stimulus and result in an error of omission. In unpaced (or subject-controlled) tasks, where the stimulus is present until the subject responds, a decrement may appear as an increase in response time (RT).

For a large number of cognitive tasks, the most robust measure of sleep loss for even very extended periods and, in some cases, the only significant measure, is the absence of a response. When the response is made it is fairly intact with respect to accuracy. However, it is evident by now, that the shorter RTs and performance accuracy are also negatively affected by sleep deprivation under given conditions (4-9).

However, what do response lapses actually measure? Are response lapses, accuracy, and RT measuring the same things, or do these three dependent variables measure different effects of sleep loss? Does measuring the response lapse alone provide the entire picture of cognitive decrement during sleep loss and of rhythmic variation over the circadian period?

VISUAL SHAPE DISCRIMINATION TASK

The paradigm allows an in-depth examination of the lapse hypothesis in a visual shape discrimination task under conditions of sleep deprivation. Responses were classified into three categories: errors of omission (missed trials), accuracy, and RT. Trial duration is several times longer than the average response lapse, thus allowing assessments of both definitions of a response lapse, extremely long response times, and errors of omission.

Visual shape discrimination was tested in a forced-choice paradigm with eight choices. A trial consisted of the presentation on a computer monitor of a target stimulus (T1) and eight comparison stimuli one of which was identical to the target (T2). The stimuli were constructed of five adjacent vertical lines of varying heights randomly selected. The target stimulus always appeared to the left of the screen; the eight comparison stimuli appeared to the right. All stimuli appeared in a single row. The location or T2 was randomized by trial. The stimuli were present until a response was made. If 15 s elapsed from trial onset without a response, the trial was terminated and a response lapse was recorded.

A trial began when the subject placed his finger on the home key. Eight response keys were arranged in an arc around and at equal distance from the home key.

The visual shape discrimination task was part of a battery of perceptual cognitive and psychomotor tests administered every 2 h over 72 h of sleep loss. Subjects arrived in the laboratory on Saturday night, went to sleep at around 2200-2300, and were up at around 0700. At 0800 on Sunday, they began the baseline-training day, which followed the same procedure as used in the sleep-deprivation experiment. All testing procedures were repeated every 2 h. At 2000, subjects ended the baseline-training day and retired at 2200-2300.

On Monday morning, subjects awoke at around 0700 and began the experimental procedure at 0800, which continued until 1200 on Thursday. Subjects were not allowed to sleep or nap even during their leisure, non testing time. They were always accompanied by lab assistants who worked shift hours. Eleven subjects participated in this experiment.

RESULTS

Response Lapses

Although the average percentage of response lapses was very small (3.16%), the changes over days and hour of the day were significant ($F(2, 20) = 3.98$; $p \leq 0.035$; $F(11, 110) = 3.01$; $p \leq 0.0015$, respectively). The number of sessions in which there are no response lapses decreases from approximately 87% to 68% over the 3 days. The number of sessions in which there are one or two lapses increases from 11% to 21% while the number of sessions in which there are three or more lapses increases from 2.4% to 10.8% ($X^2 = 14.7$; $df = 4$; $p \leq 0.01$).

Accuracy

Accuracy was generally high and stable over 3 days of sleep deprivation. There is a significant diurnal effect ($F(11, 110) = 1.88$; $p \leq 0.049$), reaching a maximum at 1800 (92.5%) and a minimum at 0400 (85.5%). Response time increased over the 3 days of sleep deprivation ($F(2, 20) = 4.33$; $p \leq 0.027$) and over hours of the day ($F(1, 10) = 5.19$; $p \leq 0.05$); RT is 5.056 s at 1800-2200 and 5.808 s at 0400-0800.

All RTs generated within each of the 3 days were collapsed and their distributions examined. The distribution of RTs and of response lapses indicate the following:

1) The major changes in the RT distributions over the 3 days involve a systematic shift in weighting from the shorter to the longer RTs in the 3-8 s range. Changes in RT are uniform and reflect a process affecting all RTs equally.

2) There is no change in the overall range of RT's over the 3 days. The RT distribution remains unimodal throughout.

3) There is a systematic increase in the frequency of response lapses over the 3 days.

Alternative Analysis of Data

Certain aspects of the lapse hypothesis are almost intuitive and intrinsically attractive. One expects that sleep loss should cause reduced arousal and attention. Sleep loss should result in an increase in erratic behavior. In fact, the frequency of errors of omission within each session does increase over the 3 days of sleep loss.

An alternative approach may be offered to interrelate and analyze errors of omission, response accuracy, and response time as a model to test the effects of sleep loss on performance. This approach stresses individual differences in susceptibility to sleep loss and consequent sensitivity to performance deficit. As sleep loss accumulates, subjects become less interested in and less capable of sustaining the attention necessary to perform their tasks. The response lapse is the end point of this process, that is, the behavioral manifestation of a "sleepy" inattentive subject. The error of omission may be considered the behavioral measure of the effect of sleep loss and utilized as an independent variable. Individual differences in susceptibility to sleep loss may be assessed by the response lapse and predict the performance deficit for that subject when "sleepy." Two points should be stressed to explain how lapses differ from other dependent variables. One, the lapse is really a measure of the organismic-state (or trait) of sleepiness rather than of performance per se. The greater the number of lapses, the "sleepier" the individual.

A recent study at the Naval Health Research Center examined the comparative use of four measures of sleepiness: the MSLT (Multiple Sleep Latency Test); response lapses in a 10-min tapping task; the SSS (Stanford Sleepiness Scale); and the VAS (Visual Analog Scale) in a study of benzodiazepines and caffeine in non sleep deprived subjects (10,11). The MSLT and lapses, significantly correlated with each other over all hours of the morning and afternoon, are sensitive to drug treatment and apparently assess sleepiness.

The second point, a corollary of the first, is that the lapse is <u>not</u> an assessment of the information processing in <u>specific task performance</u> but rather of a <u>general performance</u> level. The "absence of a response" cannot be used to assess how the subject processes information, but rather how and when the nonstimulus related circumstances lead to a cessation of responding. If a lapse reflects nonreceipt of stimuli, the stimulus characteristics and processing are not involved in that determination. Contextual parameters, general task interest, whoever keeps the subjects awake and interested should determine the frequency of lapses but not the particular type of stimulus processing involved in a specific task. Response accuracy and response time, however, being responses to the stimuli, do reflect the nature of the stimulus and processing necessary for successful performance. Therefore, the lapse is more a measure of the organismic state, while accuracy and RT reflect specific stimulus and response processing. Response lapses may be used as a measure of individual susceptibility to sleep deprivation. Accuracy and RT, in turn, may be related to response lapses as dependent variables to an independent variable.

Reanalysis of the visual shape discrimination data involved two steps. First, the changes in response lapses, accuracy, and RT from the first to the third day of sleep loss were estimated for each of the subjects, and cross correlated. Changes in response lapses and accuracy are very highly negatively correlated ($r = -0.68694$; $p = 0.0195$). Large increases in response lapses from day 1 to day 3 are accompanied by decreases in accuracy over the same period. However, the correlation between RT and response lapses and between RT and accuracy are not significant.

The second step in the reanalysis of the data involves ranking the subjects in terms of the number of response lapses over the 36 sessions, creating two post-hoc groups: those with the number of response lapses below the median ($N = 6$) and those with the number of response lapses above the median ($N = 5$).

The two groups differ significantly in the overall number of response lapses ($F(1, 9) = 6.87$; $p \leq 0.05$). The group with below median response lapses changes very little over time and over hours of the day; while the group with greater than median response lapses shows an increase in the number of lapses over the 3 days and over the hours of the day ($F(2, 18) = 4.8$; $p \leq 0.05$; $F(11,99) = 4.6$; $p \leq 0.01$). There is no general decline in accuracy across the three days of sleep loss for members of the group with below median response lapses; there may actually be an increase in accuracy. In contrast, the group with above median number of lapses shows a decline in accuracy from the first to the third day with well defined troughs at 0400 on the second and third days, as well as at 2000 on the third evening ($F(2, 18) = 4.26$; $p \leq 0.03$; $F(11, 99) = 2.17$; $p \leq 0.022$).

The difference in absolute RT between the two groups is approximately 1.5 s ($F(1, 9) = 7.88$; $p < 0.02$). Despite this large difference in absolute RT, both groups show a significant increase in RT over the 3 days of sleep deprivation ($F(2, 18) = 4.11$; $p \leq 0.023$). For both groups, the longest RTs are generated at 0600, the shortest at 2000 ($F(11, 99) = 5.31$; $p \leq 0.0001$).

The actual change in RT over the 3 days of sleep loss for the two groups relative to their base RT is fairly close. For the high-response lapse group, whose average RT is approximately 6.25 s, the increase due to sleep loss is 0.517 s, which represents an 8.3% change. The comparable change for the low-response lapse group, whose average RT is approximately 4.75 s, is o.435 s increase due to sleep loss, resulting in a 9.16% change.

Some authors (12) have suggested that the reason subjects are often able to perform reasonably well and continuously for long periods of time despite sleep deprivation may be due to their "microsleeping," which is capable of countering the effects of sleep loss and turning total sleep deprivation into partial sleep deprivation. Dement (13) suggested that "microsleeping" was analogous to "snacking" by a food-deprived individual, who, thereby, could assuage his hunger by "micro-food-intakes." Similarly, the sleep-deprived individual utilizes the microsleep to partially assuage his "sleep hunger." Sleep deprivation is ameliorated by microsleeps according to this formulation.

Microsleep has been considered the factor responsible for response lapses, including those in the form of errors of omission (14,15). If microsleeps are refreshing, one might expect that the greater the number of lapses, the less the overall effect of sleep loss on performance. This paradoxical result is not verified in the visual shape discrimination data. The opposite is true when one divides the subjects into two groups: those with higher than median response lapses and those with lower than median response lapses. Subjects with a large number of lapses show no improvement in accuracy over time and have the greater diurnal effect, while subjects with very few response lapses continue to improve their performance accuracy over 3 days of sleep loss.

This interpretation of the data relates to the response lapses as indicators of "sleepiness" and perhaps predictors of individual differences in the susceptibility to sleep loss. Subjects with greater than median number of lapses are more sensitive to sleep deprivation than subjects with fewer than the median number of lapses. Individual differences in response to sleep loss can be seen as the development of different patterns of behavior over time. Subjects whose general performance pattern is steady show relatively swift response times and fairly accurate responding, which can even improve with continuing performance. Subjects whose general performance becomes more erratic over time have generally long response times and show an increasing number of inaccuracies and larger diurnal influences on accuracy as sleep loss accumulates. However, the data alone indicate that all subjects, those with a large number of response lapses as well as those with a small number of response lapses, show increased RT as a function of sleep loss. One might almost conclude that even if you are not so susceptible to sleep loss in terms of microsleeping or inattention and you are willing, able, and capable of correct responding, nevertheless, you will be slowed down when you attempt to produce a correct response. This is not necessarily a speed/accuracy tradeoff in the usual sense of a chosen strategy to cope with a task/demand in the face of a "stressor" with opposing demands. Rather, the implication is that although one may retain the ability to attend to a stimulus, process it, and respond correctly, nevertheless sleep loss does slow down the responses.

If, as Johnson (6) and his colleagues suggest, the MSLT (Multiple Sleep Latency Test) and lapses in a tapping task are highly correlated in non-sleep-deprived subjects, could one perhaps predict cognitive performance accuracy during sleep deprivation by measuring the presleep-deprivation MSLT? Would those subjects with the longer MSLTs continue to maintain higher accuracy levels throughout the period of sleep deprivation than their short MSLT colleagues? The question of individual differences in sensitivity to sleep loss is one of the most important areas of future research on the effects of sleep deprivation on cognitive performance.

In a practical sense, the arguments presented all point to the need of separately reporting all of the response measures (the dependent variables) in a sleep loss/sustained operations study. Consequently, I have some problem with accepting "thruput" as a single index of sleep loss since it is a measure that combines several variables, accuracy, and performance duration. It may even ignore trial-by-trial RT if there is no separate trial-by-trial measure and only use an estimate of RT, that is, total task duration.

Perhaps if the object is to assess the efficiency of performance in a specific task alone (such as a simulator of a task of particular interest) and the emphasis is on that performance, then "thruput" may be a measure of choice as an engineering index. But, if the question concerns specific cognitive functions and how they are affected by sleep loss/sustained operations, then thruput can be confusing, as you do not know which of the variables is changing at any given moment. Certainly, the data we showed would argue that at any given moment, any one or all of the dependent variables may be changing. If you are testing the effect of drugs on behavior, you will not know, via thruput, even if you see improvement, whether it is accuracy that improved, or speed, or both.

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PRESENTATION 11

THE OPERATIONAL ASSESSMENT OF HUMAN PERFORMANCE DURING SUSTAINED/CONTINUOUS OPERATIONS

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OBJECTIVE

The requirement for U.S. military personnel to maintain vigilance and sustain optimal performance for long periods of time is ever increasing. Recent advances in technology have allowed for prolonged operational periods with man being the limiting factor. Many researchers have investigated various stressors that may affect performance. However, most of these studies have been performed in the laboratory. The primary objective of this paper is to discuss some of the variables that need to be included in operational studies. In addition, limitations of various laboratory procedures when applied to operational investigations are discussed.

APPROACH

The U.S. Armed Forces are spending a great deal of time and effort investigating operational performance in the laboratory setting. Various laboratories have highly specialized simulators, which are designed to replicate aspects of the environment that are thought to have a significant impact on performance. In addition, a variety of psychological and physiological techniques have been developed to assess how human performance is affected when personnel are required to perform for long periods of time. Several of these techniques have been employed as dependent measures during a recent operational study in the Persian Gulf. Their advantages and limitations were assessed.

Many researchers have extended laboratory results to explain changes that we see in operational performance. Yet, there are some significant differences between the laboratory and the operational environment. One of the major differences is the amount of boredom or monotony. Wylie and Mackie (1988) have recently presented results that indicate that monotony/boredom appears to be the highest rated stressor to affect operational performance. Another major difference between laboratory and operational studies is the actual amount of time spent on the task. More specifically, during laboratory studies, subjects are aware that they are participating only for a predesigned period of time. This knowledge, or expectation of task completion, appears to sustain operator performance. Many times in the operational environment, especially during sustained operations, the individual continues to participate in task performance long after expected completion time.

A series of physiological (i.e., heart rate, skin temperature, core temperature, etc.) and psychological (Performance Assessment Battery (PAB)) measures were collected during an at-sea evaluation of human performance. The environmental characteristics required sustained operations under high heat.

In addition, the probability of conflict was very high, thus producing a high-stress environment.

RESULTS

A more complete description of the results are provided in a series of technical reports available from the Naval Health Research Center. The dependent measures were chosen because of their high reliability in laboratory testing. However, an obvious point, which is often ignored, is that, the more operationally relevant a research procedure becomes, the less experimental control we have. Tremendous problems occur that would never happen in a laboratory study (i.e., lack of control of environmental noise and ship movement). In addition, an operational research team is an intrusion to the existing environment. Space and time need to be allocated to participate in an environment that is already overcrowded and sleep deprived. The point of this paper is that the intrusion of experimental procedures used, especially in cognitive testing (i.e., use of the PAB), provide a change in the routine or a break in their monotonous schedule, which resulted in increased or no change in performance over long periods of time. Initial conclusions might be that cognitive performance was not affected, therefore, personnel were maintaining their levels of cognitive performance over long work periods. However, so as not to interfere with actual job performance, the PAB was used as a pre/post measure. Although this procedure works in the laboratory setting, our results were somewhat surprising. Although the subjects' performance and enthusiasm were high on the PAB, their actual job performance was degraded. This result is evident when observing the subjects while on watch (as shown on the video tape). Many of the subjects displayed tremendous fatigue while on watch, some actually falling asleep. Yet, after watch, their performance on the PAB was high. They reported that completing the PAB was fun (unlike subjects in a laboratory) and was a nice change in their schedule.

FUTURE OBJECTIVES

The future objectives of sustained operations research are to develop more objective measures to evaluate human performance during operational tasks. These measures will need to maintain task relevance in order to evaluate actual job performance, rather than the current procedure of assessing subcomponents of cognitive skills by using the PAB.

PRESENTATION 12

COMBINED ARMS IN A NUCLEAR/CHEMICAL ENVIRONMENT (CANE)

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OBJECTIVES

To provide measured data and determine how well combat and support units can perform their mission in extended operations where nuclear and chemical weapons are employed in order to identify unit NBC deficiencies, develop solutions, and to take corrective actions in U.S. Army doctrine, training, leadership development, organizations, and materiel to improve the warfighting capability of the fielded force.

APPROACH

The U.S. Army is conducting a series of large-scale, force-on-force, high-resolution field tests to measure the interactions of combat, combat support, and combat-service support units during extended operations in a nuclear and chemical environment and to quantify unit performance degradation due to this environment. A 72-96-h extended operational scenario using near real time casualty assessment is conducted with units in both a basline environment (no threat of nuclear or chemical weapons) and a nuclear/chemical environment. The order of environment is varied for the units undergoing evaluation.

RESULTS

The CANE program has, so far, evaluated the effects of the nuclear and chemical environment on the mission performance of three levels of organization. CANE I evaluated mounted and dismounted operations of a mechanized infantry platoon. CANE IIA evaluated tank heavy company team operations with emphasis on weapons effectiveness, command and control, and communications at company level. CANE IIB evaluated combat operations at the battalion task force level, which included scout operations, task force level command, control and communications interaction of combined arms force and support units (maintenance, resupply, medical, engineer, decontamination, and smoke operations), air defense and live fire of field artillery and mortars. Results of these three field tests have been published and distributed in three summary evaluation reports and three supporting lessons learned video tapes. The reports are available through DTIC. The CANE I report is unclassified. The results of CANE IIA and CANE IIB are confidential.

The U.S. Army Training and Doctrine Command has an ongoing program for developing solutions, setting resource priorities, and correcting the problems. Key to this program is that the mission areas proponent is the main player in developing the fixes and is responsible for implementing the solutions.

FUTURE OBJECTIVES

The CANE evaluation of light forces (Infantry Company-Light Infantry Division) is currently scheduled for the Spring of 1991. Other tests are being planned to evaluate Army Aviation and air defense issues.

SECTION C

ATTENDANCE LIST FOR DOD SUSOPS TG

PENSACOLA, FLORIDA

11-12 JULY 1985

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SECTION D

CHARTER

SUSTAINED/CONTINUOUS OPERATIONS

SUBGROUP OF THE DOD HFE TG

Charter
Sustained/Continuous Operations
Subgroup of the DOD HFE TG

GOAL

Provide a mechanism for the exchange of technical information for application of Research, Development, Test, and Evaluation (RDT&E) methods and technologies as they apply to sustained/continuous operations. To provide input to DOD decision makers and doctrine developers on sustained/continuous operations issues.

Enhance middle-management and working level coordination among government agencies involved in RDT&E of sustained/continuous operations to make possible the application of the best methodologies and technologies for study of the topic.

Identify human factors technology gaps and requirements for advancement in the state-of-knowledge relevant to sustained/continuous operations.

Encourage and sponsor in-depth technical interaction on the topical areas of human performance during sustained/continuous work, various work/rest schedules, circadian rhythms, and sleep/rest management in military operations.

Assist, as required, in the preparation and coordination of tri-service documents such as Technology Coordinating Papers and Topical Reviews on Sustained/Continuous Operations.

SCOPE

The scope of activities of this group shall include the exchange of information, the working level coordination, and the identification of requirements for all technical areas that are applicable to improving equipment operator performance and manpower utilization during sustained/continuous military operations.

For the purposes of this working group, the term sustained/continuous operations refers to a work schedule that demands steady work productivity during a course of time that goes beyond a "normal" duty cycle and usually involves the onset of fatigue and/or some sleep deprivation.

SUBGROUP

TOPICAL AREAS

The Subgroup will address a variety of human-factor variables that affect performance in sustained/continuous operations, particularly in the operation of equipment and military systems. The general topics of concern to the Subgroup include, but are not limited to:

1. Work/rest schedules- periods of time: work-to-rest ratios.

2. Circadian rhythmicity- biological rhythms as they vary with respect to time.

3. Alertness and sleep deprivation- adequate amounts of sleep essential for alertness.

4. Sleep discipline- strategies used to ensure proper rest, for example, taking naps.

5. Fatigue-

a) physiological decreases in performance over time, and

b) psychological state: feelings of tiredness, change in motivation, mood, affect, activation, and decrease in cognitive-mental activities.

6. Pharmacological intervention- use of drugs to enhance or sustain performance.

7. Rapid deployment demands- extended operations, translocation disruptions, for example, jet lag.

8. Sustained performance with unique equipment systems (e.g., electro-optical sighting devices, chemical protective clothing, high-performance aircraft).

9. Sustained performance in unique environments (e.g., heat, cold, altitude, space).

SUBGROUP COMPOSITION

The composition of the sustained/continuous operations Subgroup will be consistent with the policies of the DOD HFE TG.

Membership in the Subgroup is open to U.S. Government employees, members of academia, private and industrial research organizations, and other interested parties whose work involves them in topics of sustained/continuous operations. Participation of members of U.S. Allied Military Forces is encouraged, subject to individual approval by the Office of the Undersecretary of Defense for Research and Engineering (OUSDR&E), sponsor of the DOD HFE TG.

Members of the Subgroup are encouraged to participate in all Subgroup meetings and activities. (However, although Subgroup membership per se is rather open, under DOD HFE TG policy, only U.S. Government employees are permitted to participate in the full DOD HFE TG meetings, unless invited for a specific purpose.)

OPERATING BOARD

The Subgroup Operating Board is responsible for the conduct of Subgroup business and the implementation of TG policies. The Board provides continuity and structure necessary for the organization and planning of efforts pursuant to Subgroup goals.

The Subgroup Operating Board shall be composed of two representatives from each participating U.S. military service. These representatives must have technical backgrounds in the areas of sustained/continuous operations. It is intended that the two board members from each service represent a combination of responsibilities for research/development and implementation management of sustained/continuous operations technologies within their respective service.

Subgroup Board members may be selected by service caucus or be nominated by their respective service.

CONDUCT OF BUSINESS

Meetings of the Sustained/Continuous Operations Subgroup will be held semiannually; one meeting must be held in conjunction with a semiannual DOD HFE TG meeting.

Subgroup Chairship will rotate among represented services biannually, in odd-numbered years beginning in 1985. Chair-select will be determined by the Operating Board caucus.

Additional Subgroup officers required (e.g., treasurer, secretary) will be selected by majority vote.

All charges or requests for services of the Subgroup will be received through the Chair for action by the Subgroup Operating Board.

All responses from the Subgroup will be delivered by the Chair, or his/her designated representative, as defined through majority opinion.

Minutes of meetings will be recorded, reviewed, and transmitted by the Subgroup Chair in accordance with policies of the DOD HFE TG.

The Subgroup Operating Board will receive and place priorities on problems to be addressed by the Subgroup. Where appropriate, working groups will be established for addressing particular problems.

Working groups will be chaired by a member of the Operating Board. Membership of working groups will not be restricted to employees of the government and will be nominated by its Chair for approval by a majority of the Operating Board. Working groups will develop plans on a milestone basis and will provide reports of progress at least annually.

Presenters at meetings are required to submit a copy of their presentation and hardcopies of their visual materials to the Subgroup Chair for inclusion in the meeting minutes.

SECTION E

SUSTAINED WORK, FATIGUE, SLEEP LOSS, AND PERFORMANCE:
A REVIEW OF THE ISSUES

WORK & STRESS, 1989, VOL. 3, NO. 2, 129–141

Review Paper

Sustained work, fatigue, sleep loss and performance: a review of the issues

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The physiological and psychological stressors associated with sustained work, fatigue, and sleep loss affect worker performance. This review describes findings relating to sustained work stresses commonly found in our advancing technological world. Researchers report decrements in sustained performance as a function of fatigue, especially during and following one or more nights of complete sleep loss, or longer periods of reduced or fragmented sleep. Sleep loss appears to result in reduced reaction time, decreased vigilance, perceptual and cognitive distortions, and changes in affect. Sleep loss and workload interact with circadian rhythms in producing their effects. These interactions are a major source of stress in work situations requiring sustained work in continuous operations and have implications for theoretical models of sustained perceptual and cognitive functioning.

Keywords: Fatigue; Sleep deprivation; Sustained work; Continuous performance; Continuous operations; Circadian rhythms.

1. Introduction

Human productivity is often epitomized by work schedules that employ workers around-the-clock: such uninterrupted schedules of nonstop activity are known as 'continuous operations' (CONOPS). Individuals involved in CONOPS often work a regularly scheduled 'normal shift length' (7–12 h) and then are relieved by others while the overall operation continues. Workers later return to the job as scheduled and presumably after adequate rest and sleep. Examples of CONOPS range from chemical process and energy production plants through police, fire and rescue operations, transportation, communication, and food services, to operating worldwide investment marketing centres, and many others. Technological innovations, such as night vision systems for military forces, can serve to promote increased around-the-clock activity. CONOPS often imposes on workers psychological and physiological stresses that have a negative impact on productivity, accident, and absenteeism rates (Colquhoun and Rutenfranz 1980, Johnson *et al.* 1981, Alluisi and Morgan 1982, Folkard and Monk 1985, Tepas *et al.* 1985, Tepas and Monk 1987).

Many individuals work on shifts longer than 12 h, often performing at close to a nonstop rate for as long as they can. These unusually long work stints are referred to as 'sustained operations' (SUSOPS). Often they are not planned, but must be continued until a goal is reached. They generally last long enough for workers to experience fatigue and sleep loss. This often leads to reduced performance, efficiency and effectiveness. Examples of SUSOPS include: staffing hospitals during internship, performing lengthy emergency medical operations, long rescues, evacuations at disaster sites, fighting forest fires, military training missions, combat operations, aerospace missions, sailing in a storm and participating in endurance sport activities. In the more conventional CONOPS shiftwork setting, workers occasionally participate in bouts of SUSOPS during periods of 'overtime' work.

Often SUSOPS workers are asked to maintain acceptable levels of sustained performance, staving off fatigue and performance decrements. A number of factors associated with sustained work affect the psychological and physiological condition of workers and moderate job performance during SUSOPS. These are reviewed here.

1.1. *Characteristics of the job, work tasks*

1.1.1. *Continuousness of tasks*

The extent to which a job requires sustained effort affects performance. Some jobs require long hours of constant attention, prolonged uninterrupted activity, and/or stamina often in a monotonous or repetitive environment. Crosscountry truck driving and lengthy periods of monitoring radar are two examples of this. Other jobs involve periods of continuous work interspersed with markedly reduced activity, lulls, or even rest breaks. Piloting long-haul flights with sufficient crew, processing paperwork, and making computer entries are three examples of this. SUSOPS workers who continuously perform cognitive tasks for extended periods show predictable performance decrements. Angus and Heslegrave (1985) required subjects to do 54 h of continuous work simulating handling of message traffic and information processing. They found reaction time, logical reasoning, vigilance, encoding, and decoding declined after 18 h work in a stepwise manner, dropping over the next 6 h to 70% of baseline. Performance was stable at 70% for the next 18 h, declining over the next 6 h to 40% of baseline, and then remaining stable at 40%. Deterioration of mood and motivation, and increases in subjective reports of sleepiness and fatigue paralleled the decline in performance. Furthermore the greatest declines in performance over successive nights without sleep coincided with the trough of the circadian cycle (0300–0600 h). In another study, Mullaney *et al.* (1983, 1985), using a computerized test battery for 42 h, obtained similar results.

1.1.2. *Vigilance and attention*

Mackworth (1957) refers to vigilance, or monitoring tasks, as requiring a state of maximum physiological and psychological readiness to react. Vigilance characterizes an observer's ability to detect and respond to small stimulus changes that require direct attention to sources of stimulation for long, unbroken periods of time, such as watching a radar screen (Mackworth 1957, Davies and Parasuraman 1982). Although many jobs require continuous monitoring for two or more hours, the quality of sustained attention on such tasks wanes rapidly.

Observers become progressively less efficient at detecting either visual or auditory signals as vigilance time continues (Stroh 1971, Mackie 1977, Warm 1984). 'Vigilance decrement' is characterized by a drop in the number of correct detections and/or by a rise in response time to correct detections. Most studies suggest vigilance decrement can be expected as early as 20–35 min after initiation of a vigil, although this depends on factors like the background event rate, the sensory modality, and amplitude of critical signals. In addition, environmental stressors, such as heat, cold, noise, vibration and the state of alertness (fatigue level) of the observer can affect performance during prolonged periods of sustained attention.

There are many work situations in which failure to detect critical signals can be disastrous, for example, an anesthesiologist monitoring medical displays during surgery or an operator monitoring control panels at a nuclear power plant. Short monitoring stints of less than 4 h have been recommended (Warm 1984), but are not always practical for these jobs.

1.1.3. *Machine-paced versus worker-controlled tasks*

In machine-paced, or event-driven tasks, these factors control when a response is to be made. Reaction time and task duration are important in predicting machine-driven task performance. In contrast in a completely worker-controlled task, the worker determines when the item to be responded to appears, its duration, and the time within which the response must be made. Reaction time is thus less important in worker-controlled tasks, and task duration will be more variable. Examples of worker-controlled tasks include making telephone sales calls or entering information into computers.

Salvendy (1981) estimated that over 50 million workers perform predominately machine-paced tasks. Machine-pacing can provide consistent production rates, but the resulting performance demands may increase the stress on workers. In SUSOPS, performance differs as a function of the type of job pacing. Performance on machine-paced tasks is often affected by small amounts of sleep loss leading to errors of omission (Williams *et al.* 1959).

1.1.4. *Physical versus cognitive tasks*

Sustained intense physical effort can lead to muscle fatigue, and eventual failure to perform, just as sustained cognitive work can lead to general feelings of fatigue or weariness, and in the chronic extreme, to 'burn out'. The main effects of any associated sleep deprivation appear to be psychological rather than physiological (Haslam and Abraham 1987, Haslam 1982, Englund *et al.* 1985, Martin *et al.* 1986).

The main effect of sleep loss on physical capability is a slowing of the biological recovery process in response to muscular exercise and therefore there is a subsequent need for a slightly longer recuperative period (McMurray and Brown 1984).

Sleep loss also hastens the onset of, and increases the frequency of cognitive performance decrements, especially on attention demanding vigilance tasks during sustained work. Performance on cognitive tasks involving memory, learning, logical reasoning, arithmetic calculations, pattern recognition, complex verbal processing and decision making has been shown to be impaired by sleep loss to a measurable extent beyond that anticipated by the effects of sustained effort alone (Babkoff *et al.* 1985, Englund *et al.* 1985, Haslam and Abraham 1987). However, the degree to which performance is impaired by sleep loss does depend upon task variables such as duration, knowledge of results, difficulty of task, task pacing, proficiency level, task complexity, and memory requirements (Johnson 1982).

1.2. *Rhythmic variations in worker performance*

Workers exhibit various predictable physiological and behavioural rhythms, within a period of about a day, i.e., circadian rhythms. Alertness declines most as body temperature decreases to its lowest level from 0300–0600 h and to a lesser extent from 1600–1800 h (Minors and Waterhouse 1985, Monk *et al.* 1985).

For most people, night-work is a problem because it calls for an overriding of circadian variations and demands (Tepas and Monk 1987, Monk and Embrey 1981, Folkard and Monk 1979). This presents a paradox for workers expected to sustain performance around the clock.

Worker performance not only varies with time-of-day, but also interacts with work schedule and may result in different time-of-day effects for different tasks (Monk and Embrey 1981, Monk *et al.* 1983). The simple generalization that workplace performance is poorest in the early morning hours must therefore be qualified. Some work schedules may result in the best performance for one type of task in the early morning hours and yield the poorest performance for another type of task at the same time of day (Folkard and Monk 1979).

'Ultraradian rhythms', cyclical variations in efficiency and alertness having a period of less than 12 h are also seen in sustained work. Several authors have described ultraradian rhythms in terms of a commonly occurring 90-min cycle patterning, but usually in relation to biological processes such as sleep stage patterning, pupil dilation, duration of the spiral after-effect, and digestive functioning. The 90-min rhythm is common, but is often masked in data where it might be expected to appear (Lavie 1982, Hockey 1986).

By way of overview, it is worth noting that Trumbull (1966) has described 50 normal patterns of neuro-physiological and psychological rhythms within humans that have various degrees of influence upon their level of performance and ability to maintain performance.

1.3. *Weariness, tiredness and fatigue*

'Physical fatigue' may be thought of as the temporary loss of power to respond, induced in a sensory receptor or motor end organ by continued stimulation. It is the muscular tiredness one feels after sustained vigorous exercise, repeated lifting, or digging. Physiologists describe it as a decrease in physical performance (Simonson 1971, Simonson and Weiser 1976); but often it has a strong cognitive component (Hockey 1986). The decision that muscular work (e.g., pulling a dynamometer handle) is no longer possible can occur well before the physiological limit has been reached. Caldwell and Lyddan (1971) showed 'maximal pull' was greater if subjects expected longer rest pauses between trials.

'General fatigue', sometimes referred to as 'mental fatigue', is the subjective feeling of weariness which accompanies repeated performance of almost any nonphysical task. The lack of novel stimuli brings on feelings of monotony and boredom, accentuated by tiredness and drowsiness associated with sleep loss. Grandjean (1968) interprets this general fatigue as a consequence of reduced afferent impulses or reduced feedback from the cortex to the reticular activating system. Somewhat by contrast, Bartley (1965) viewed fatigue as a 'whole' symptom felt throughout the body, attributable to physiological changes in internal organs. Boredom can become apparent within minutes of the onset of a monotonous task (O'Hanlon 1981), but mental fatigue typically is a product of hours of continuous work.

Holding (1974) demonstrated, after 24–32 continuous hours on a multiple-performance battery, that fatigued subjects, who are given a choice of effort level and corresponding probability of success, are more likely to choose a strategy of low effort/low probability of success. Hockey (1986) suggests prolonged periods of cognitive overloading puts individuals into states where any further effort to meet task demands is aversive. This normally leads to shortcuts and inconsistent application of task-related behaviour. This, Hockey (1986) argues, amounts to a strategic change rather than a fundamental reduction in operating efficiency. However, sleep deprived subjects improve in their cognitive performance when they hear a nap soon will be permitted (Haslam 1985 a). Thus the notion of 'aversion to effort' may be central to the demonstration of both physical and mental fatigue. However, we often see fatigued workers suddenly stop their work, be it physical or cognitive, and vigorously participate in sporting activities, or computer games during 'break'.

Hockey (1986) also differentiates short-term fatigue effects from those of prolonged cognitive overloading, calling them 'phasic fatigue' which he says may represent fundamental changes in the level of system efficiency. Phasic fatigue can result from prolonged vigilance in which the worker occasionally exhibits an unusually long response time, misses signals, exhibits brief interruptions in performance (lapses in attention), makes more errors of choice, or, maintains accuracy, but sacrifices speed of performance and consequently accomplishes less work per unit time.

Since fatigue is predominately subjective, it is hard to quantify. Skill performance studies show, in addition to increased reports of 'feeling fatigued', workers also change their patterns of attention with prolonged work. As early as the 1940s, Bartlett (1942) noted fatigued pilots make larger control errors – though generally less often – and timing of coordinated movements and manoeuvres becomes less accurate, while instruments and actions attended to only occasionally are likely to be forgotten. Unrecognized and uncontrolled fatigue almost always gives rise to marked irritability. Similar more recent findings with helicopter pilots were reported by Lees *et al.* (1979) and Krueger *et al.* (1985 a).

1.4. *Work rest-breaks, work shifts and work/rest cycles*

Change *per se*, i.e., novel stimuli, plays a significant role in overcoming the effects of fatigue. Thus, work breaks or pauses, and split shifts are ways of overcoming acute fatigue effects.

1.4.1. *Work-rest breaks*

Although there are not many hard data to defend short rest breaks, there is limited evidence to support the assumptions that short breaks in 'machine-paced' jobs are beneficial in terms of alleviation of fatigue, that they do not reduce output even though less time is worked, and in some cases can lead to increased productivity and employee satisfaction (McCormick and Tiffin 1974, Alluisi and Morgan 1982). The benefits of rest pauses in most sedentary and light physical activities may derive more from subjective factors like relief of boredom. Where repetitive heavy physical activities such as lifting are involved, rest, or changes-of-activity can preclude muscle fatigue and cardiac strain (McCormick and Tiffin 1974).

Optimum schedules of rest pauses have not been determined for different kinds of work, workers, and conditions of work. With the present trend toward jobs that require more cognitive work, the issue of rest breaks deserves new examination. Janaro and Bechtold (1985) describe attempts to determine optimal rest break scheduling models for developing policies to minimize fatigue and optimize work output.

1.4.2. *Shift work schedules*

Alluisi and Morgan (1982) remind us that in 1890, blast furnaces kept men working 12 h per day, 7 days per week for 84-h workweeks. Later reductions in the length of the workweek resulted in decreases in accidents, absenteeism, and in some cases, increased productivity. However, it is clear that the effects of total work hours on human performance and productivity interact with many other factors. No single work schedule is likely to be optimum for all tasks or all industries.

If there are sufficient personnel to maintain continuous productivity, individual workers can follow alternating shiftwork schedules. Daily shifts may vary from 8 h of work followed by 16 h off duty, or 12 h on–12 h off to more continuous schedules alternating sequences of 4 h of work followed by 4 h off duty, or 4 h work with 2 h off duty (Chiles *et al.* 1968, Alluisi 1969). Depending on local custom, the nature of the work, and the type of workers (e.g., part vs. full-time), many alternative schedules permit CONOPS.

1.4.3. *Work/rest cycles: SUSOPS in small teams*

Continuous operations often means employing crews of 2–3 personnel, charged to perform 24-h per day. Although military operations are not always analogous to industrial shiftwork, some of the basic tenants are similar. Instead of going home at shift change, the soldier, sailor or airman scheduled to alternate with a team member on the job ('shiftworkers') usually rests or sleeps nearby, even in the crew compartment or workstation itself.

Operation of ships or submarines presents a variety of scheduling problems including those relating to work shifts, meals, sleep, and recreation. Kleitman and Jackson (1950) focused on sleep and body temperature in identifying the advantages of different ship-watch schedules, beginning with various alterations to 'standardized' rotating shifts of 4 h on and 8 h off duty. They concluded the closer ship-board schedules are to typical shore-based work–rest cycles the better the adaptation of body temperature to the activity cycle. Because performance was positively correlated with temperature, crew performance would be improved by following such schedules. Colquhoun *et al.* (1968 a, 1968 b, 1969) conducted naval-watch studies on alternating shifts to compare 3-person 8-h rotating shifts with 2-person 12-h shift schedules. Two-person shifts, because they were stabilized, exhibited higher mental task performance efficiency, better adaptation, and better maintenance of 24-h work.

In preparation for aerospace missions, Chiles *et al.* (1968) conducted a set of comprehensive and informative studies of rapidly alternating work rest schedules. Subjects with work-to-rest ratios of 1 : 1 participated in one of four work–rest cycles for 4 continuous days: (*a*) alternating 2 h on duty and 2 h off; (*b*) 4 h on and 4 h off; (*c*) 6 h on and 6 h off; or (*d*) 8 h on and 8 h off. Regardless of the schedule, performance scores on vigilance, computational, target identification, and crew code-lock solving tasks improved throughout the 96 h. In a similar study of work–rest ratios of 2 : 1, subjects were scheduled 4-h on duty and 2-h off around the clock for 4 days; and for a ratio of 3 : 1, were scheduled 6-h on and 2-h off (Chiles *et al.* 1968). Both schedules gave clear evidence of circadian variations in all performance measures, but neither was significantly better than the other. Subjects preferred the 4–2 over the 6–2 schedule and the former averaged 5·5 h of sleep per 24-h period, whereas those on the 6–2 schedule averaged less than 4 h sleep.

Subsequently, in 15-day (360 h) and 30-day (720 h) confinement studies, employing 4–2 and 4–4 schedules respectively, those on the 4–4 schedule maintained consistently better levels of performance than those with the 4–2 schedule. When one 15-day group was shown psychophysiological and performance data of another group, and was told their goal was to prevent the appearance of circadian low points, they were able to do so, demonstrating benefits of feedback and motivation. Overall, Chiles *et al.* (1968) showed that: (1) subjects working 12 h per day on a 4–4 schedule can maintain generally higher levels of performance than subjects working 16 h per day on a 4–2 schedule; (2) some subjects can work 16 h per day on a 4–2 schedule with essentially no decrements over a period of at least 15 days; (3) when subjects are highly motivated, performance over a period of 30 days on a 4–4 schedule is indistinguishable from the levels maintained by subjects following a stabilized 8-h split-shift in a nonconfinement situation; and (4) 16 h per day on a 4–2 schedule appears to be the maximum hours per day a man should work for extended periods.

1.5. *Effects of sleep loss*

The most important concern in sustained work is the effect of sleep loss. When workers perform for extended periods and lose sleep, the accumulating sleep loss degrades performance, mood, and attitude. In instances where limited amounts of intermittent and broken sleep are obtained, that sleep generally is of insufficient quality to restore cognitive functioning and performance to peak levels.

Many writers have discussed the effects of sleep and sleep loss (e.g., Kleitman 1939, Webb 1968, 1982), and there are voluminous reports on human performance in work settings (e.g., Dunnette 1976, Salvendy 1982, 1987, Boff *et al.* 1986). Although attempts to merge the two topics began about the turn of the century, (Patrick and Gilbert 1896), applications of research on the effects of sleep loss and sustained performance in the working world have been rather recent (Englund and Krueger 1985, Krueger and Englund 1985, Krueger *et al.* 1985 b, Krueger and Barnes 1989).

1.5.1. *Lapse hypothesis of sleep loss decrements in performance*

When an individual is required to sustain work and is sleep deprived, it is common to witness occasional 'blocks', or brief periods of no response, that increase in frequency and duration, while performance between blocks is maintained at close to initial levels (Bills 1931). Bjerner (1949) introduced the more general term 'lapses' for 'blocks' and found them in the form of long reaction times coinciding with long periods of reduced arousal. Bjerner (1949) regarded lapses during sleep deprivation as reflecting brief periods of sleep, or a condition like 'microsleeps' (1–10 s), an approach followed by Williams *et al.* (1959) in their seminal work on the topic.

Williams *et al.* (1959) kept subjects awake for at least 72 h, and sometimes as long as 98 h. In simple experimenter-controlled (machine-paced) reaction time (RT) tests, they found the difference between slowest and fastest responses became greater as lapses increased in duration; and as lapses increased in frequency, the distribution of reactions showed more long RTs. They showed that sleep deprived subjects are capable on some trials of coming very close to their best RTs of earlier baseline periods, but that there is an enormous increase in duration of the longest reaction times. The subjects' poorest performances became progressively worse, even though their best performances remained close to original levels. Continuing sleep loss produced an increase in frequency and duration of lapses, but performance between lapses was at an acceptable but generally reduced level. Sleep loss also consistently produced impaired performance on experimenter-controlled vigilance tasks using auditory, visual, or vibratory stimuli. Performance lapses were related to speed and only indirectly to accuracy as errors of omission. As sleep loss progressed, errors began to appear earlier in the task and the benefits from an initial effort, or a break between parts of the task, became increasingly short lived.

On a variety of tasks (addition, communication, and concept attainment) in which the subject controlled the time at which a response was made or the interval between responses (worker-paced jobs), the consistent result was a change, not in accuracy, but in the rate of performance or speed of response. These slower speeds stemmed primarily from an increase in the frequency and duration of lapses. They were also affected by the same task properties that gave rise to little or no change in accuracy: the subject had an unlimited response time which allowed for the delay of a response or for the correction of errors, and the usual orientation toward correctness which prompted the subject to sacrifice speed for accuracy, (Williams *et al.* 1959).

Williams *et al.* (1959) studied additional conditions that affected decrements attributable to the lapse hypothesis, and found that: (1) altering the level of motivation, especially by providing knowledge of results, tended to reduce impairment, but the differences were small and inconsistent; (2) exhorting subjects to perform better produced only slightly better performance and only on single stimulus tasks; (3) increasing the complexity of a communication receiving task resulted in more errors of omission; (4) with sleep loss, subjects frequently failed to acquire and recall information quickly, and this led to an increasing number of items 'missed'; (5) with increasing sleep loss, there usually is a decline in EEG alpha amplitude associated with errors of omission; and (6) there is significant recovery after sleep.

In a more recent 72-h total sleep deprivation study (Thorne *et al.* 1983, Babkoff *et al.* 1985), subjects were tested hourly on a variety of perceptual and cognitive tasks requiring 30 min to complete. The tasks, ranged from the simple to the complex, including logical reasoning, memory, serial addition and subtraction, pattern recognition, complex verbal processing, and vigilance. As sleep deprivation continued, the average time on task increased at an accelerating rate. The rate of increase differed among tasks, with longer tasks showing greater increases than shorter ones and confounding sleep deprivation and workload effects. Performance on all tasks deteriorated in parallel with a deterioration in mood, motivation, and initiative. Performance on the cognitive tasks declined roughly 25% for every 24 h of semicontinuous work without sleep. As the subjects became more tired, the cognitive testing, which initially took only 30 min out of each hour, took longer to complete, so by 72 h subjects were working continuously. Declines in cognitive performance correlated with circadian fluctuations in body temperature.

There are many other studies on the effects of sleep loss on sustained performance, including those which point out that workers do not adapt well to restricted sleep schedules though they may think they do (Carskadon and Dement 1979, 1981); that prior experience with sleep loss does not train one to cope with the deleterious effects of sleep loss on performance (e.g., Webb and Levy 1984); that higher rates of sleep fragmentation lower the recuperative value of the sleep and minimize restorations in cognitive functioning (Stepanski *et al.* 1984); that particular sleep stages are relatively unimportant to performance (Johnson *et al.* 1974); that naps often benefit subsequent task performance (Naitoh *et al.* 1982, Naitoh and Angus 1987, Dinges *et al.* 1985); and the degree to which sleep loss impairs performance on a variety of tasks increases with age (Webb and Levy 1982, Webb 1985).

1.6. *Sustained and continuous performance studies*

Some military studies have been carried out using actual work schedules necessitating sleep loss. Drucker *et al.* (1969) required 2-man teams to operate continuously at compensatory tracking and target-identification tasks for a 48-h period. Significant performance decrements were observed with both tasks, especially during the usual sleep period. Rotation of tasks between members of teams did not enhance performance or abate deterioration. In a series of SUSOPS field studies, 36 to 48 h in length, Banks *et al.* (1970) reported fairly stable performance on three infantry tasks (surveillance-target acquisition with a night vision device, rifle firing, and grenade throwing) with individual performance variations gradually attributable to fatigue during vigilance.

Ainsworth and Bishop (1971) studied 4-man tank crews doing offensive, defensive, and retrograde movements for 48-h SUSOPS. Crews performed communication, obstacle course driving, target surveillance, dynamic gunnery and maintenance without serious performance decrements. The authors concluded that activities demanding a protracted high level of alertness or complex perceptual-motor activity, such as moving surveillance and driving, were most sensitive to loss of sleep, that tank crew performance was not affected significantly by circadian periodicity and that although it was acceptable for a 48 h stretch without sleep tankers slowed down their overall performance of tasks. Caille *et al.* (1972) found 64 to 72 h of sleep loss did not severely impair the overall 'fighting capabilities' of well trained and highly motivated naval enlisted men. Of several tasks, only long term memory and decision making showed performance decrements.

Morgan *et al.* (1974) studied work efficiency during a 7-day study consisting of 4 h on duty, followed by 4 h off duty, 4 h more on duty, and then 12 h off duty for each of 2 days; then continuous work for 48 h followed by a 24-h period of rest, and 2 additional days of work according to the 4–4–4–12 schedule. Performance during the embedded 48-h SUSOPS was influenced significantly by circadian rhythm. Decrements first occurred after 18 h of continuous work and performance decreased to an average of 82% of baseline during the early morning hours of the first night. It then improved to 90% of baseline during the second day, but decreased to approximately 67% that night. All performance recovered to baseline levels following the 24-h period of rest.

In another study, three parachute regiment platoons participated in a field study of continuous infantry operations (Haslam *et al.* 1977, Haslam 1985 b, Haslam and Abraham 1987). One platoon was permitted no sleep, another was allowed 1·5 h sleep, and the third was permitted 3 h sleep per 24 h in a 9-day exercise. Military performance, including shooting, weapon handling, digging, marching, and patrolling, was assessed throughout. Subjects completed a daily battery of cognitive tests, which included map plotting, encoding/decoding, short term memory, and logical reasoning.

The platoon allowed no sleep was militarily ineffective after 3 nights without sleep and all members of the platoon withdrew from the exercise after 4 nights without sleep. Thirty-nine percent of the 1·5 h-sleep platoon withdrew after 5 nights and this platoon was judged to be militarily ineffective after 6 days. The platoon sleeping 3 h per night remained effective the entire 9 days.

In a related study, infantry soldiers were scheduled no sleep for 90 h of continuous activity, and then allowed 4-h blocks of sleep in every 24 h for the next 6 days (Haslam 1978, Haslam and Abraham 1987). All subjects completed these trials. In both studies the main effect of sleep deprivation was psychological rather than physiological; mental ability and mood deteriorated, whereas physical fitness did not. Vigilance and the more difficult and detailed cognitive tasks deteriorated most. After three nights without sleep, performance on these tasks deteriorated to near 50%, and in some cases as low as 35% of control values at which point they were judged to be militarily ineffective. Simple and well learned tasks, like weapon-handling tests, suffered little. Vigilance shooting, an event paced task, deteriorated markedly, while performance on a self-paced shot grouping task did not.

In general, there was a rapid decrement in the cognitive tests over the first 4 days of sleep loss, after which performance tended to level out for those subjects remaining in the field. As tiredness increased, sergeants found a more relaxed style of leadership to be appropriate, and exhortation to be better than direct orders. In the later stages of sleep-deprivation, most soldiers felt attention to detail was no longer required of them and personal hygiene and self-care deteriorated.

In this second study, 4 h of sleep on each of 3 nights was sufficient to restore performance and mood to the average control level on the following day. After the first 4-h block of sleep, performance improved to 60% of control values and after the third 4-h block of sleep, performance improved to 80% of control values where it remained for the last 3 days of the trial. The exception to this overall positive effect was that performance on the cognitive tests administered immediately after awakening remained low (sleep inertia) even after several nights in which 4 h of sleep were obtained. The utility of obtaining 4 h of sleep within each 24-h period for restoring and sustaining performance was confirmed (Haslam 1982, 1985 a). Four hours of sleep divided into 4 1-h blocks was as restorative as 4 h of continuous sleep. Further, after 3 days without sleep, anticipation of a 2-h nap produced a substantial improvement in performance.

In a study of pilot performance during extended flight operations, six aviators flew a helicopter for 11·5 h per day on each of five 20-h workdays with 3·5 h of sleep per night (Kimball and Anderson 1975, Lees *et al.* 1979). These pilots flew 32 different manoeuvres once per hour during their workday. In a second study, pilot–copilot crews flew 14 helicopter simulator hours per 20-h workday for 5 days, sleeping about 4 h each night (Krueger *et al.* 1985 a). All 12 pilots completed these two 5-day studies without major incident. However, while the psychomotor component of flight performance did not degrade to unacceptable levels, by the fourth day, pilots adopted a more passive flight control strategy, making less frequent, but larger cyclic control inputs. More important, by the fourth day pilots made occasional errors of omission (possibly lapses), like forgetting to make safety or communication checks, and simulator copilots occasionally fell asleep in their less active role as navigator. These studies indicate with just 3·5 to 4 h sleep per night, trained soldiers can control and manoeuvre complex man–machine systems for 12–14 h a day for at least 5 days, albeit at a cost in terms of efficiency and safety.

Artillery fire direction centre (FDC) teams participated in a 3-day simulation of sustained tactical battle operations working on maps, plotting preplanned and unplanned targets, with concurrent fire missions that often were superimposed with calls for preplanned fire (Bandaret *et al.* 1981). Degradation of performance was evident within the first 24–48 h. All four teams elected to withdraw from the study by 48 h. Teams made more errors as time passed, but generally remained effective until the time of their withdrawal. Performance of individual self-initiated activities (e.g., working out preplanned fire missions, revising preplanned data on the basis of new information, and keeping up the situation map) deteriorated most. As in the Haslam studies, teams in which leadership and cohesion were good, functioned better, and persevered longer. Thus, generally it can be said that under sleep deprived conditions, a well-led unit may outperform an indifferently led one. However, superior leadership cannot overcome large quantitative differences in sleep obtained or lost (Belenky *et al.* 1987).

A number of driver fatigue studies (e.g. Brown 1965, Brown *et al.* 1967) have concluded that a continuous 12-h period of driving during the normal working day need not affect either perceptual or motor skills adversely. In a simulation study of automobile driving, sustained performance was studied in 15 young adult males who performed a primary tracking task and a variety of secondary tasks over a 15-h period (Ellingstad and Heimstra 1970). Tracking performance decreased significantly over the course of the study. Secondary-task performances were markedly variable over the 15 h, with no clearly established decrements in performance.

Thus, some sustained operations studies produce seemingly conflicting results, possibly suggesting more attention to individual differences is needed. Furthermore, wide differences in study designs, the degree of experimental control, the fidelity of simulation, the measurement methodology and technology, and the choices of dependent variables make it difficult to determine general principles and to extrapolate from basic studies to predictions of real-world sustained work performance. More quality research needs to be conducted in this area (Englund and Krueger 1985, Krueger and Englund 1985) since these findings have implications for theoretical models of sustained perceptual and cognitive functioning and have obvious application to sustained military, but perhaps to civilian industrial operations as well.

1.7. *Naps and their effects on sustained performance*
Conventionally, naps mean brief sleep periods, especially during the day, to supplement or replace sleep normally obtained at night. Naps serve as a break, a change of pace from the work being accomplished and if they are long enough to provide restorative sleep, they can refresh the worker. It is common practice for workers in some countries to take a siesta in early afternoon. The length, number, quality, and placement of maps interspersed into continuous work/rest schedules, are important for their effects on sustained performance.

Many authors use the term 'nap' to refer to a short period of sleep even when that is the only sleep obtained in a 24-h period. Thus, a 'nap' or a 'short night's sleep' can differ depending upon the literature one reads. Most sleep researchers agree naps restore degraded functioning and that 4–5 h of sleep should be taken in an uninterrupted period to prevent impaired performance. The continuity of sleep theory (Naitoh and Angus 1987) postulates that continuous sleep has greater recuperative power, based on notions of importance of the duration of various stages of sleep obtained. If sleep occurs in short pieces over 24-h it is much less effective, even if the total sleep time is the same (Naitoh 1981, Naitoh and Angus 1987, Hartley 1974).

Naitoh and Angus (1987) discuss naps in the context of sleep management, a programme to maintain human functioning by preplanned napping during prolonged work periods. They contend a nap is effective in maintaining performance and mood when it is taken prophylactically before anticipated sleep loss and fatigue. However, immediately upon awakening from a nap, performance decrements may occur, sometimes up to 15 or 20 min after awakening. These sleep inertia effects are evident for a wide variety of tasks (Dinges *et al.* 1985) and should be anticipated if a worker is expected to wake quickly and respond to immediate performance expectations. Researchers present conflicting interpretations about the effects of the duration of naps on performance, the recommended timing or placement of maps in the work/rest schedule, the quality of rest/sleep obtained during naps, and sleep inertia effects (Dinges *et al.* 1988).

1.8. *Pharmacological intervention*

Various military research programmes have and are examining the potential for pharmacological intervention to sustain or enhance performance in CONOPS. Hypnotic drugs can induce sleep in the off-duty shift. Baird *et al.* (1983), documented use of a benzodiazepine (temazepam) for aviation crews in the off-duty hours to induce sleep before returning to flying duties in the Falkland conflict. Storm and Parke (1987) cite sleep and operational performance data from US Air Force fighter pilots after temazepam induced sleep in the off-duty period. The Israeli forces administered hypnotics to promote sleep among troops (passengers) during the air deployment portion of the Entebbe raid, and O'Donnell (1986) proposes the use of benzodiazepines in military aerial deployments across multiple time zones as a prophylactic to jet lag (O'Donnell *et al.* 1988).

The major concerns with hypnotics include the amount and quality of sleep/rest obtained with particular drug doses, whether or not users can awaken easily during drug-induced sleep and quickly respond normally in event of emergency. By contrast, some researchers argue for use of 'nonsedating' sleeping aids like the amino acid 1-tryptophan for military use (Spinweber 1986). Other concerns include whether there are lingering effects on performance after one awakens from the sleep period; and the effects of repeated use.

In select circumstances, stimulants can be used to maintain alertness to meet extended performance demands. Jones (1985) suggests that during the Second World War Soviet personnel used drugs to stave off fatigue and drowsiness, and to improve memory and concentration. During the Vietnam War, methylphenidate and dextroamphetamine were carried by US long range reconnaissance patrol soldiers. Jones (1985) says these soldiers found the most efficacious use to be upon completion of a mission when fatigue developed and rapid return to base camp was desirable. Other than mild rebound depression and fatigue after the drug was discontinued, no additional adverse effects were reported. However, Holloway (1974) has reported problems with abuse of stimulants by the soldiers brought about their discontinuation.

Concerns with stimulant drugs include their wide-ranging and not well-understood effects on bodily biochemistry and physiology, and especially their effects on performance. Some stimulants distort perception and affect safety, produce rebound effects like depression and fatigue, require subsequent increased doses to produce the same effects, and are likely to be addicting.

1.9. *Other factors*

Worker performance during SUSOPS is influenced by the interaction of several other factors: prior rest quantity, physical fitness, endurance, environmental conditions, number of sustained work episodes, time of day of performance, task type, workload, and motivation (Englund *et al.* 1983). For example, although one should be rested before engaging in sustained operations, we cannot store sleep, but prior rest will stave off the detrimental effects longer. All other things being equal, the state of physical fitness of individuals will affect stamina in many sustained work efforts, particularly those with extensive physical components. Noise can lessen the effects of sleep loss in auditory vigilance tasks. Tasks of high interest can prolong motivation to perform.

2. Discussion

Theoretical research must deal with SUSOPS/CONOPS stresses as they affect individual information processing. From this review of the issues it should be clear that psychological models of sustained performance must account for continuing operating demands of long work stints, for fatigue, sleep loss, circadian rhythms etc., and delineate performance predictions as functions of task type, account for scheduling of rest breaks, levels of motivation and other intervening variables.

A variety of important SUSOPS/CONOPS research questions remain. What are the tradeoffs in efficiency, productivity, and effectiveness if one works longer work-shifts, albeit at reduced efficiency, in situations where faster performance is not so critical, but hiring and training additional employees would be cost prohibitive? Do we raise the overall productivity level of the individual worker a sufficient amount to justify having him or her work those extended hours? What implications are there for flexitime employees who schedule 15 h or more work per day to complete their 'work week' in 3 days or less? Is there a point at which work efficiency reaches diminishing returns? Ultimately, there is the question of whether or not there really is an optimum work week. It should be clear that sustained operations, whether they are planned or unplanned, bring about new research concerns of worker stress and raise issues of productivity and performance effectiveness.

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SECTION F

FORM FOR DIRECTORY/MAILING LIST

DIRECTORY/MAILING LIST FOR SUSTAINED/CONTINUOUS OPERATIONS SUBGROUP

1. Please make the following changes to the current Directory/Mailing List.

Name ______________________________
(include rank/Ph.D.)

Mailing Address ______________________________
(include code, title)

____

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(include ZIP)

Telephone ______________________________
(include commercial & AUTOVON)

2. Please add/delete the following names.

Name ______________________________
(include rank/Ph.D.)

Mailing Address ______________________________
(include code, title)

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(include ZIP)

Telephone ______________________________
(include commercial & AUTOVON)

Mail to:

Dr. Carl E. Englund
Naval Health Research Center
P.O. Box 85122
San Diego, CA 92138-9174

Or telephone (619) 553-8443, AV: 553-8443